Tagging Michel Electrons in MINERvA

Dun Zhang

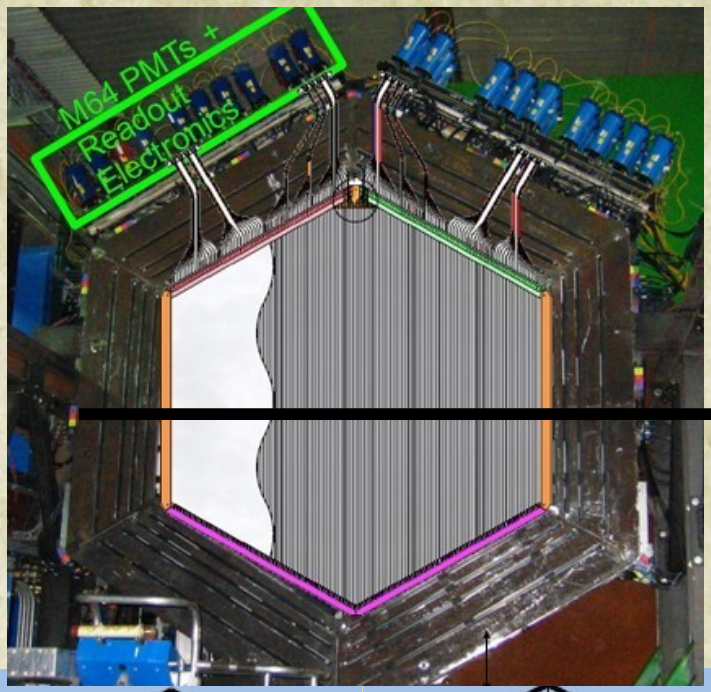
College of William and Mary

2011-05-31

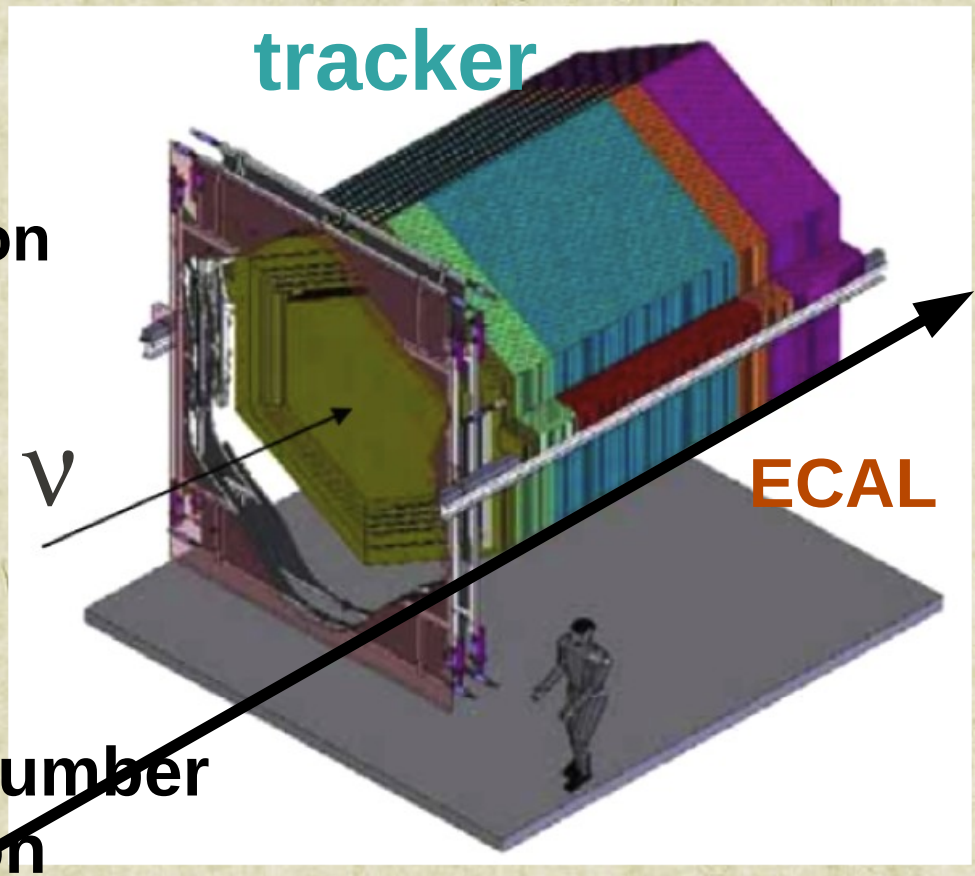
Outline

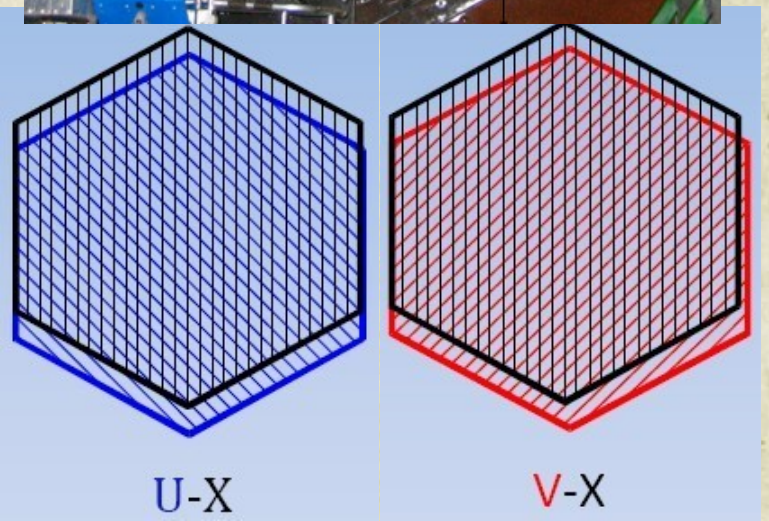
- Overview of Minerva detector
- Introduction to Michel electrons and their properties in MINERνA detector
- Procedures to tag Michel electrons
- Results from tagging Michel electrons using MC and RECO data for different part of our detector
- Summary

Detector's Overview



Strip number
X/U/V direction





Module number
Z direction

Introduction

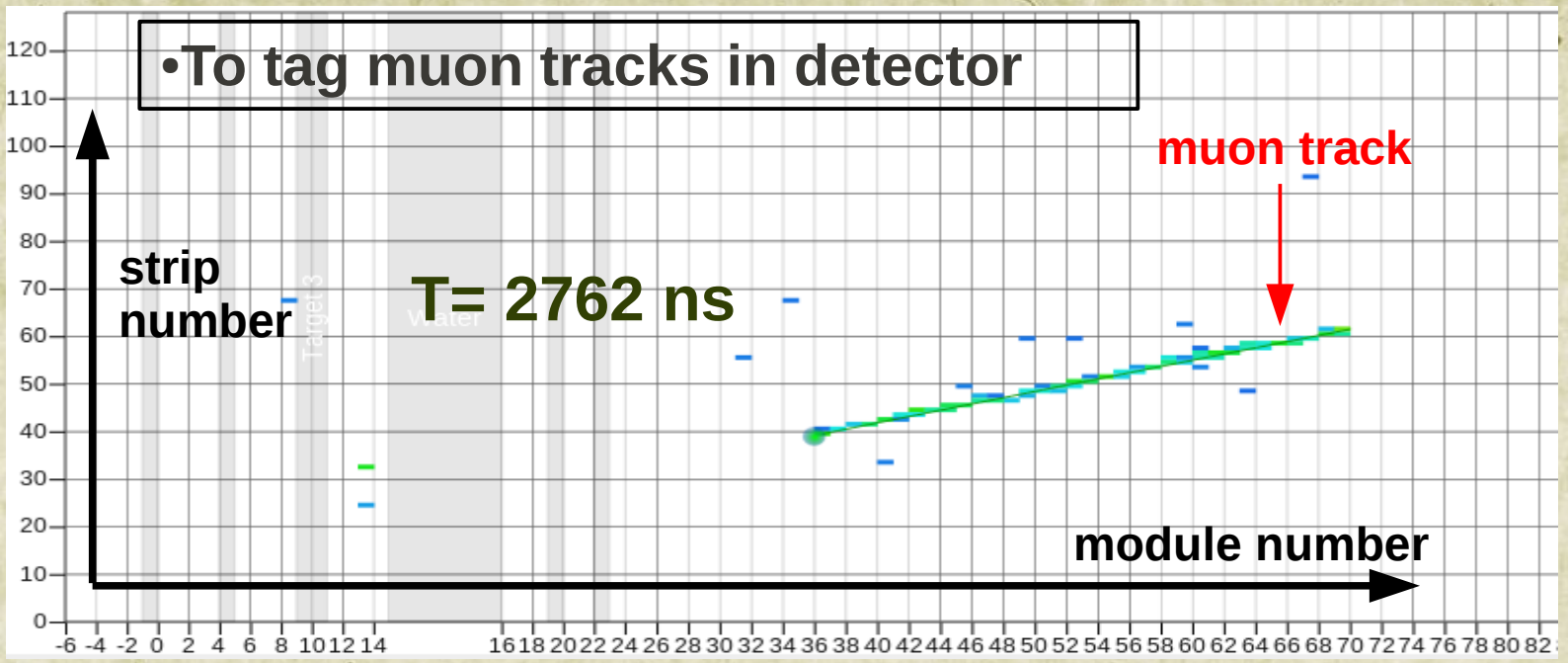
- The dominant decay mode of muons is to decay into an electron, an electron antineutrino and a muon neutrino.

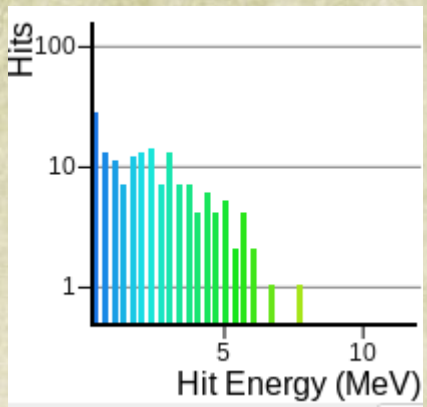
$$\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$$

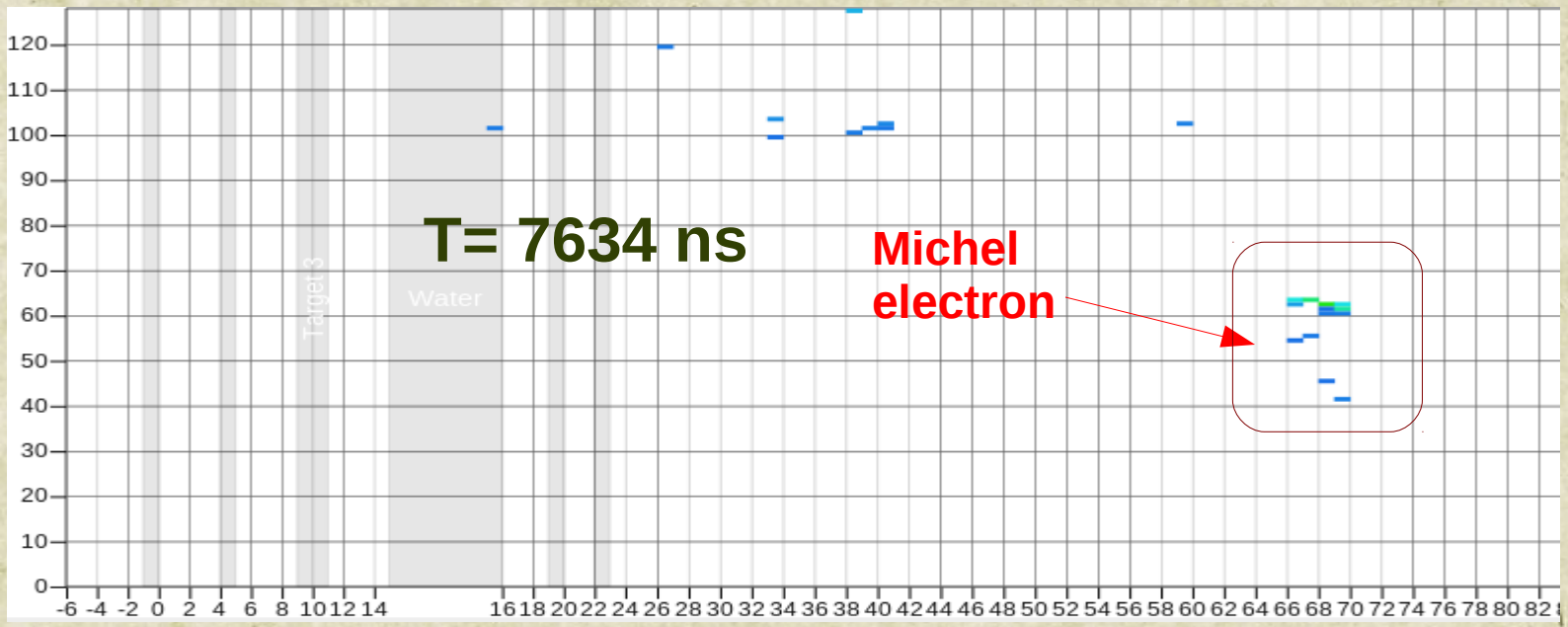
$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$$

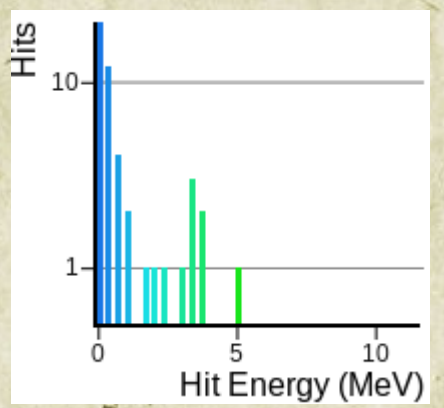
- The electron produced in muon decay is named Michel electron.
- Muons could be captured by Minerva detector, and the capture rate is about 7.8%. It will produce a neutron and a neutrino, sometimes photon.

Application









More Applications

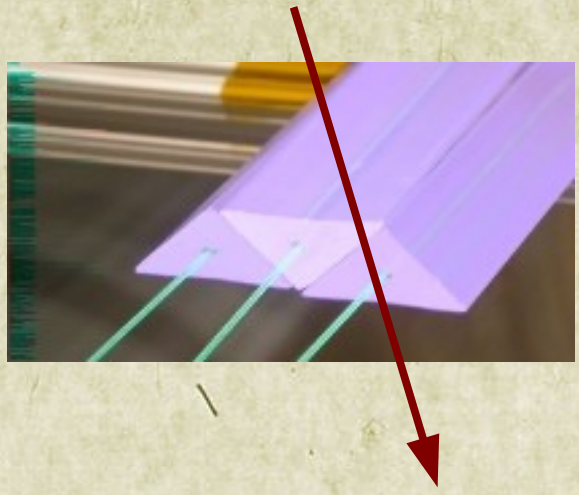
- To identify low energy pions coming out of neutrino interaction vertex via

  $\pi \rightarrow \mu\, \nu \rightarrow \quad e\, \nu\, \bar{\nu}$

- To calibrate the detector's energy scale
- To validate the attenuation correction

Properties in Detector

- We focus on the tracker and ECAL region of Minerva detector. Tracker is 1.7cm thick plastic scintillator and ECAL contains 2mm thick lead absorber per scintillator plane.

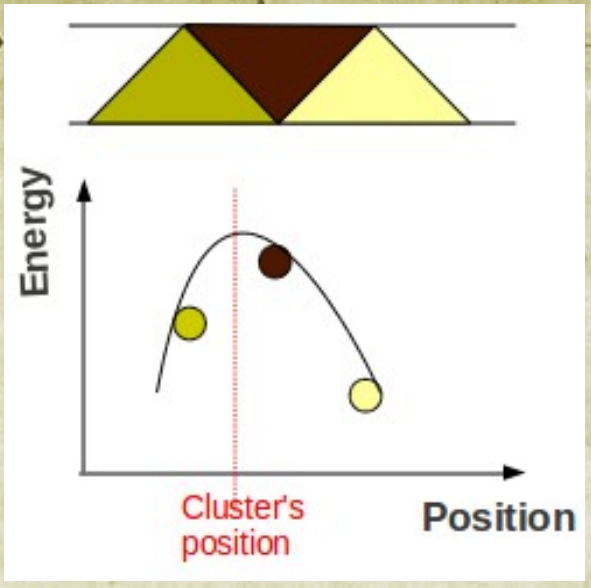


- Maximum energy of Michels is **53 MeV**.
- Electrons with energy of 53 MeV can travel around **30 cm** in our scintillator.
- The decay time of negative muon is **2026 ns** in carbon and **2190 ns** in vacuum.

Tagging Procedure

- We study every track which stops in the tracker or ECAL
- Look at the events later than the track
- Loop over the clusters in the event in three different views and for each cluster, check whether it is 'Qualified Cluster'
- If we find qualified clusters in two or three views, tag them as two view/three view Michel electrons. If we find qualified clusters in one view and the summed energy is greater than 10 MeV, tag it as one view Michel electron.

Qualified Clusters



- A cluster is a collection of single scintillator strip hits
  - Energy is the total energy of all hits
  - Position is the energy weighted position
- Qualified Cluster requires:
  - Total energy > 1 MeV
  - Along Z direction, distance to the track's end < 8 cm
  - Along X/U/V direction, distance < 12 cm
- Qualified Clusters are part of tag so the requirements are strict

Interesting Reconstructed Quantities

- **Energy**: add all the clusters' energy in the 30 cm region near the end of track
- **Decay time**: choose the time difference between the track and the earliest qualified cluster
- **Distance**: the smallest distance among all distances from the qualified clusters to the track's end
  - Note that: for some events, only 2D distance can be calculated

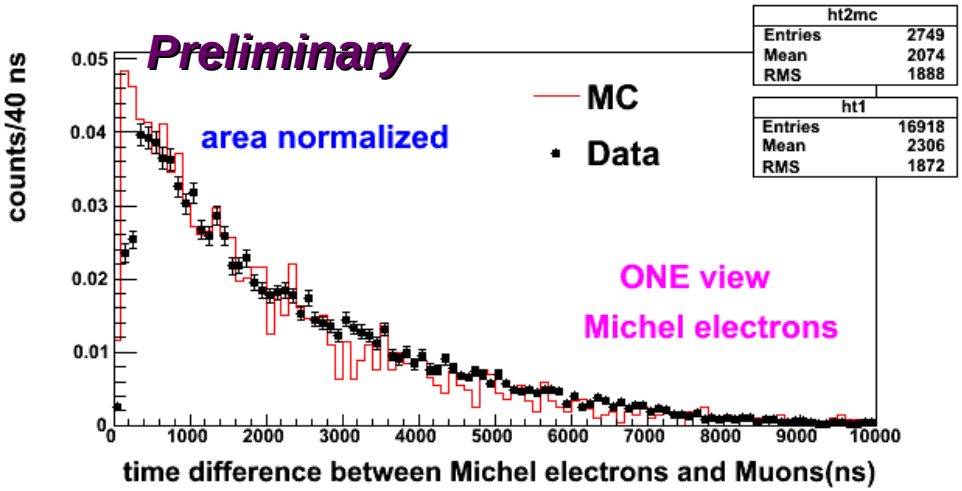
MC Study in Tracker

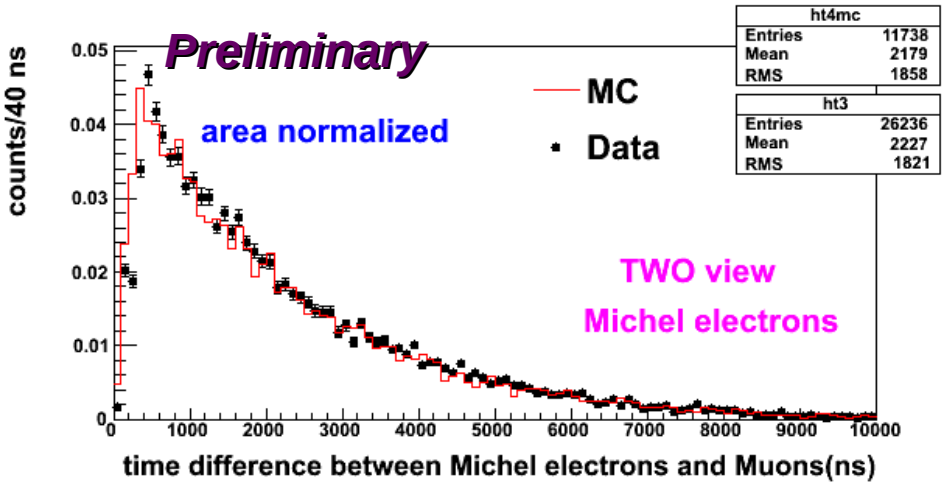
- The data was generated from muons with momentum 300 MeV/c starting at the middle of detector

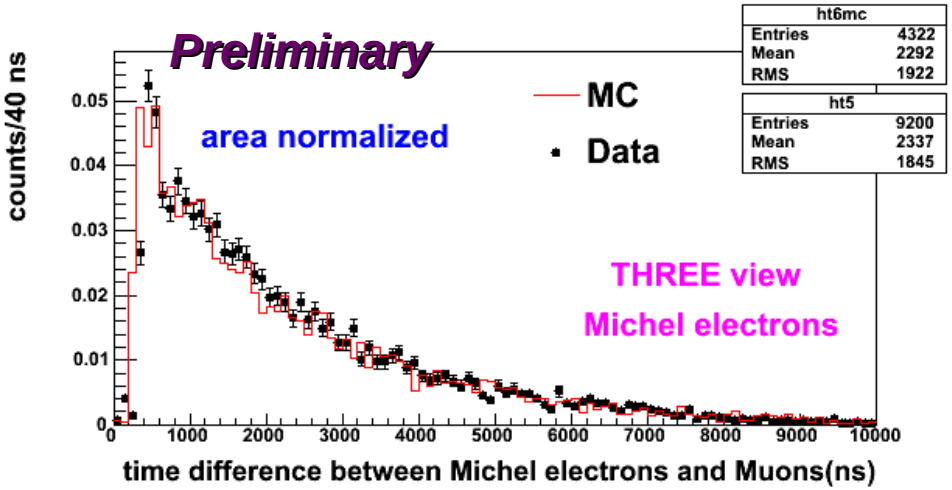
Preliminary

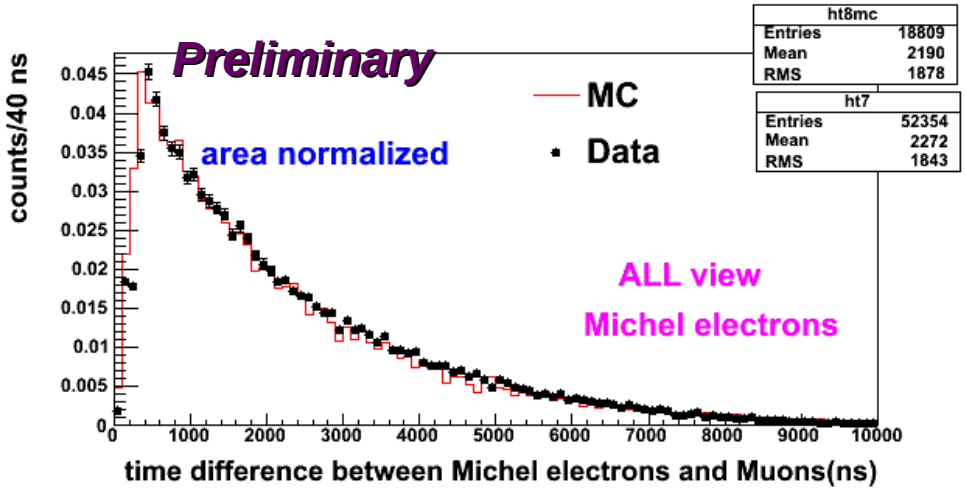
<table>
<tr><td rowspan="4">Total incoming muons
2000
↓
Reconstructed contained tracks
1424
↓
Stopped in tracker
1108</td><td colspan="3">Two view and three view Michel electrons</td><td>785</td></tr>
<tr><td rowspan="3">Remaining tracks</td><td rowspan="2">Found qualified cluster in one view</td><td>Energy > 10 MeV</td><td>123</td></tr>
<tr><td>Energy < 10 MeV</td><td>32</td></tr>
<tr><td colspan="2">No qualified cluster found</td><td>168</td></tr>
</table>

Decay Time: Data vs MC









Muon Lifetime from Fitting:

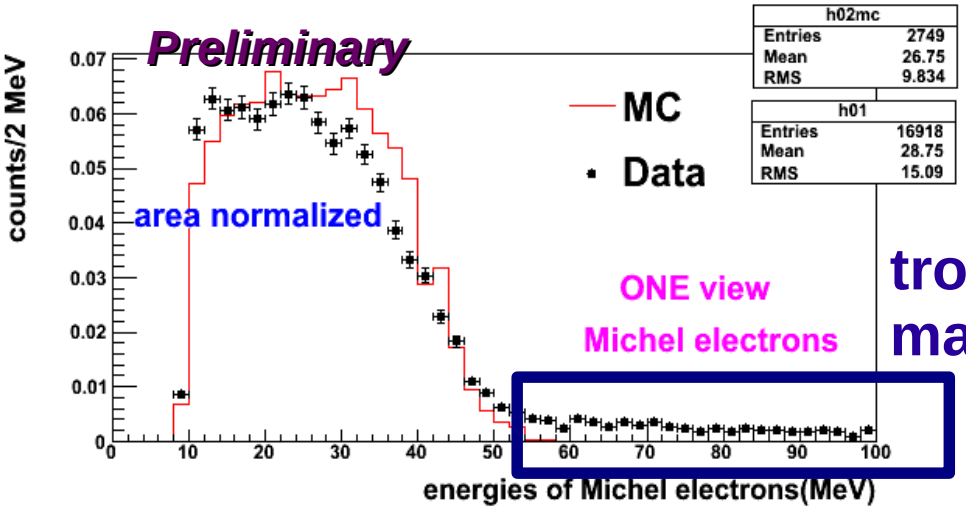
Preliminary

Tracker	Monte Carlo (ns)	DATA (ns)
One view Michel	1950 ± 60	2330 ± 30
Two view Michel	2110 ± 30	2120 ± 20
Three view Michel	2120 ± 50	2130 ± 30
All Michel	2120 ± 20	2200 ± 10

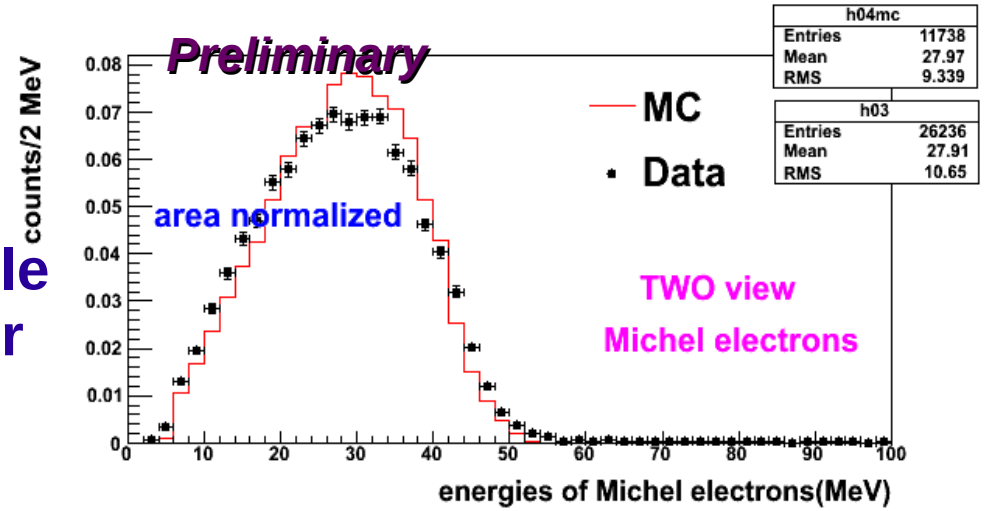
μ^- $\mu^+ + \mu^-$

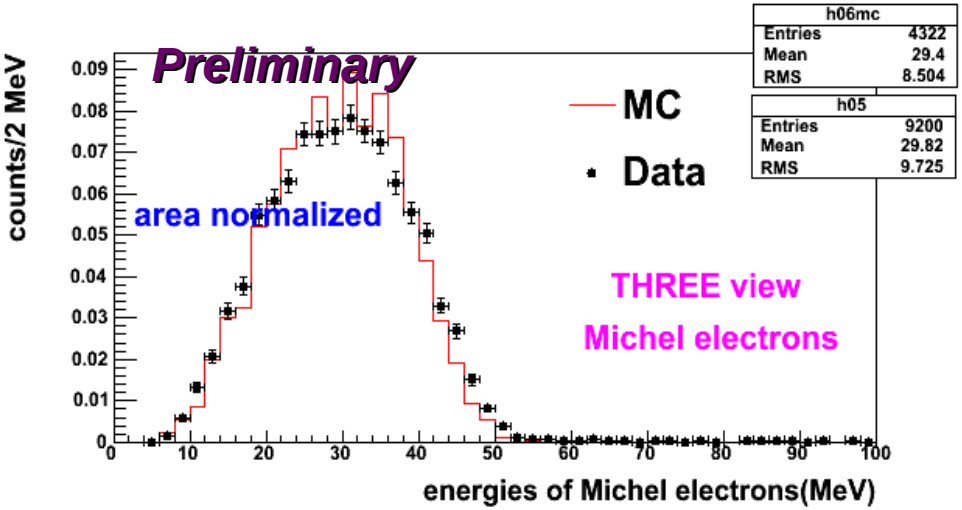
- Results are within around 2 σ of nominal lifetime in carbon
- MC is pure muons coming into the detector while data saw a combination of μ^- and μ^+, mostly μ^-.
- We will see a possible explanation why one view Michel performed poorly

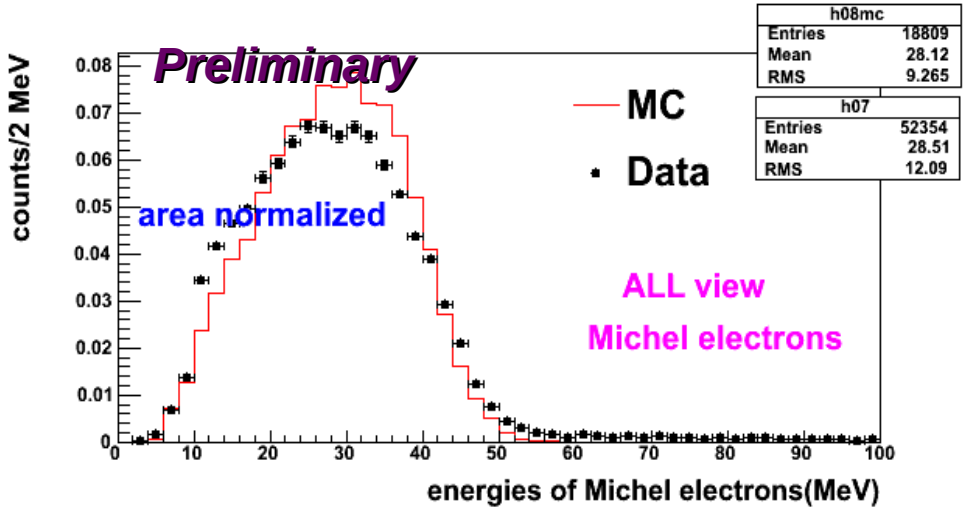
Energy Distributions



trouble maker

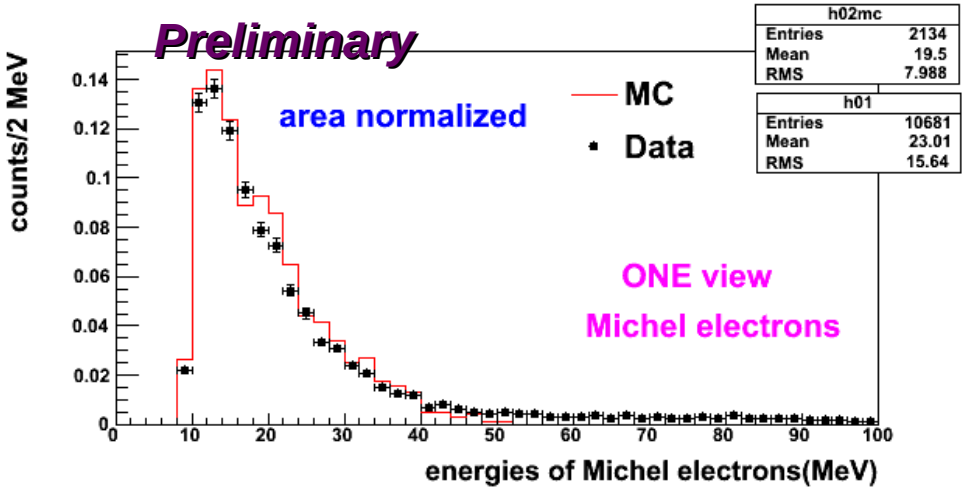


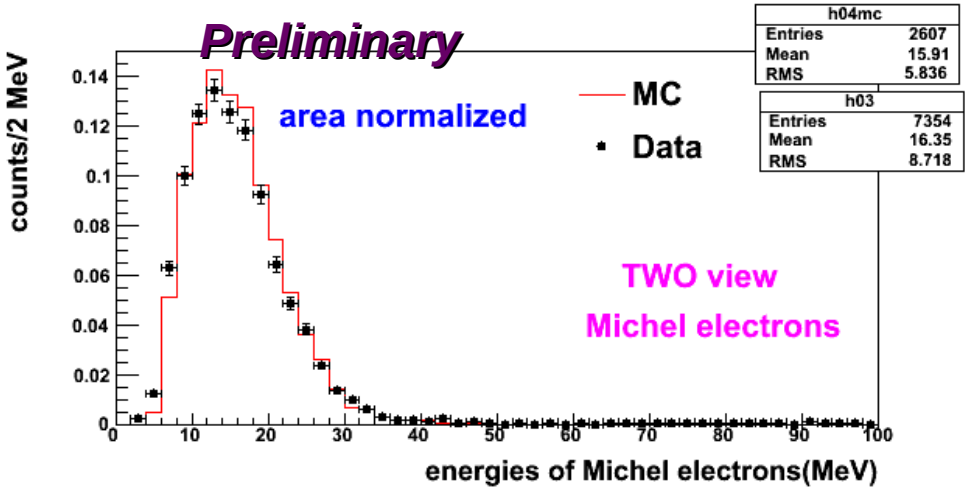


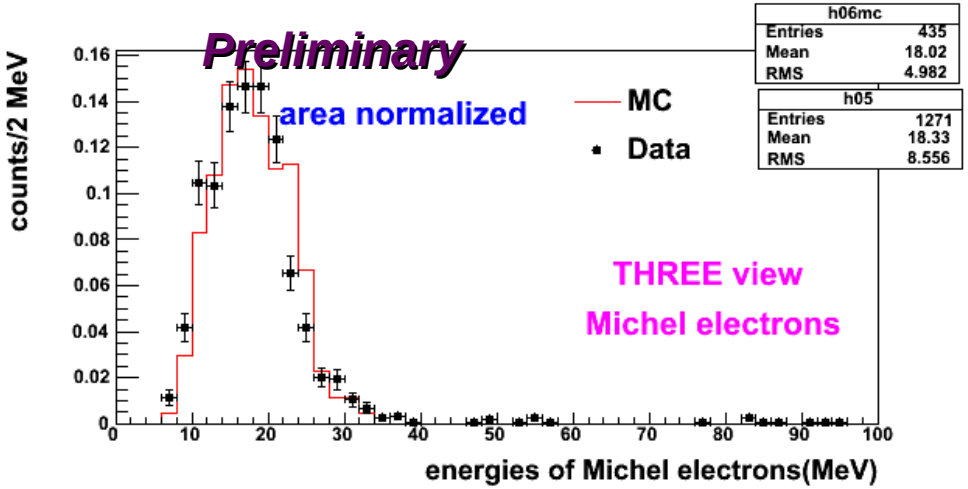


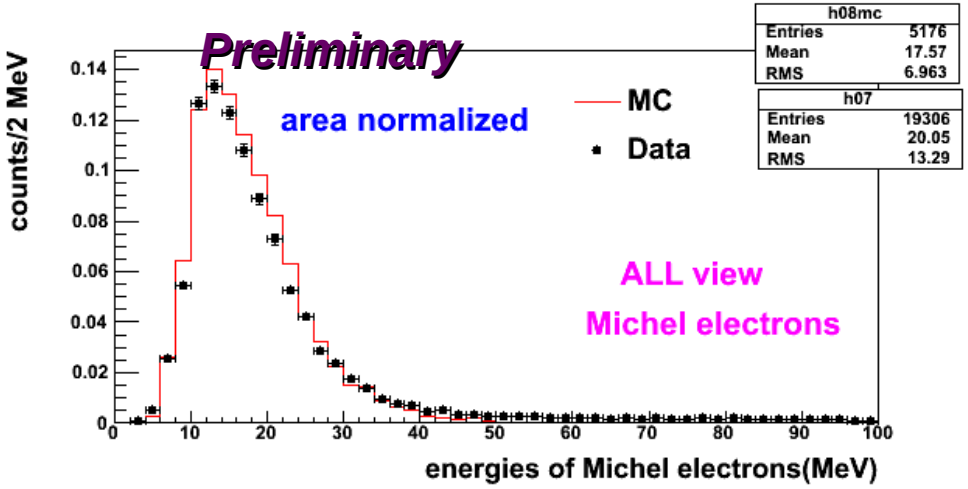
Energy Distributions in ECAL

The electromagnetic calorimeter (ECAL) has one 2 mm Pb absorber per scintillator plane.









Summary

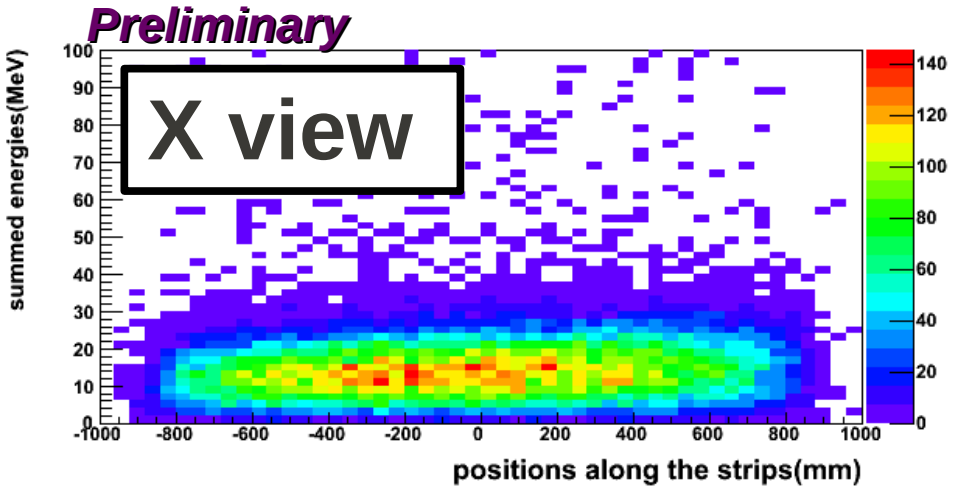
- Michel electrons can be used to tag muon tracks, pion near the vertex and calibrate the detector's energy scale.
- We have written an algorithm to select electrons produced in muon decay.
- We will try to improve the efficiency and characterize the performance of our algorithm.
- Three topological categories: three view and two view have good efficiency and low background. Events that only show up in one of the three possible views have higher background.
- The energy distributions from data and MC agree very well, and the decay time distributions look reasonable but we don't understand them perfectly.

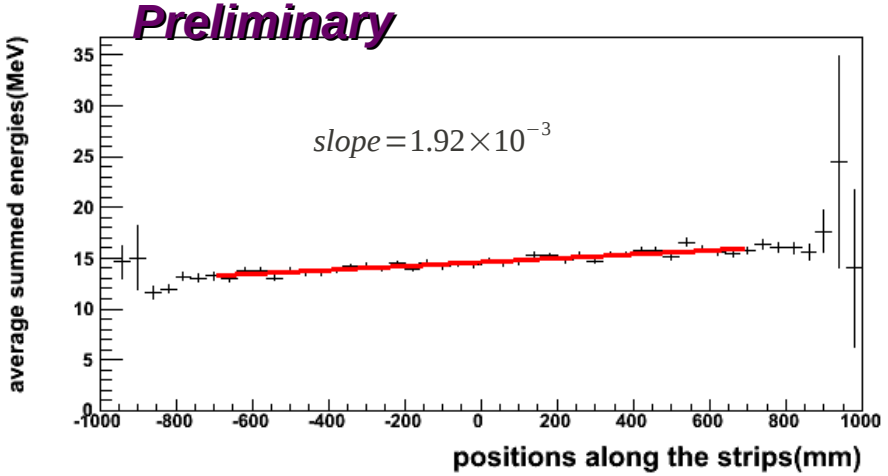
Thank you!

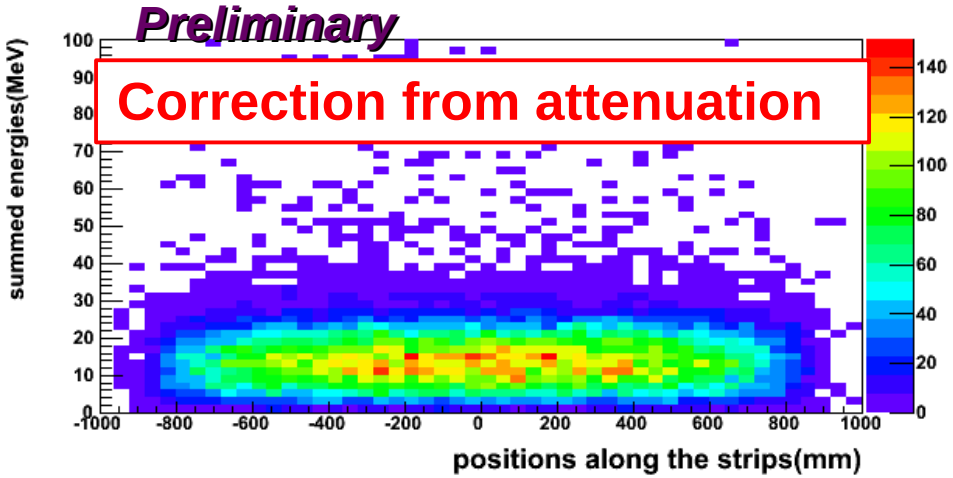
backup

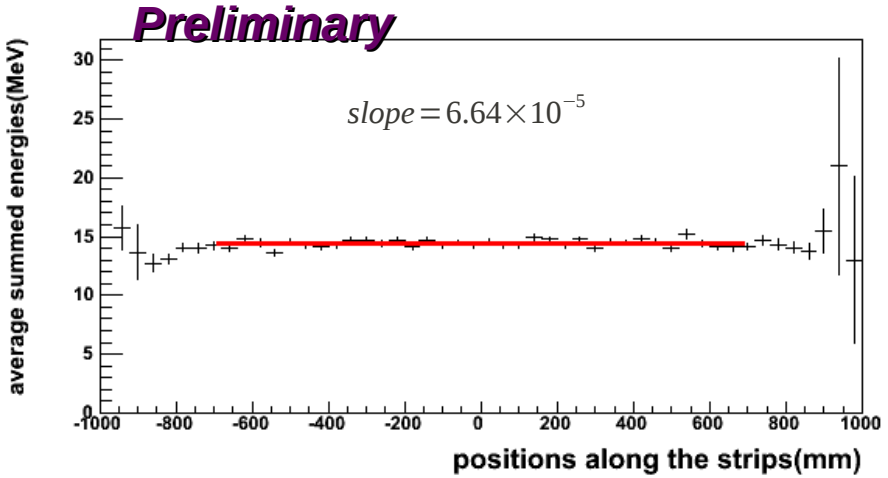
Attenuation Correction

- Used to validate the attenuation correction



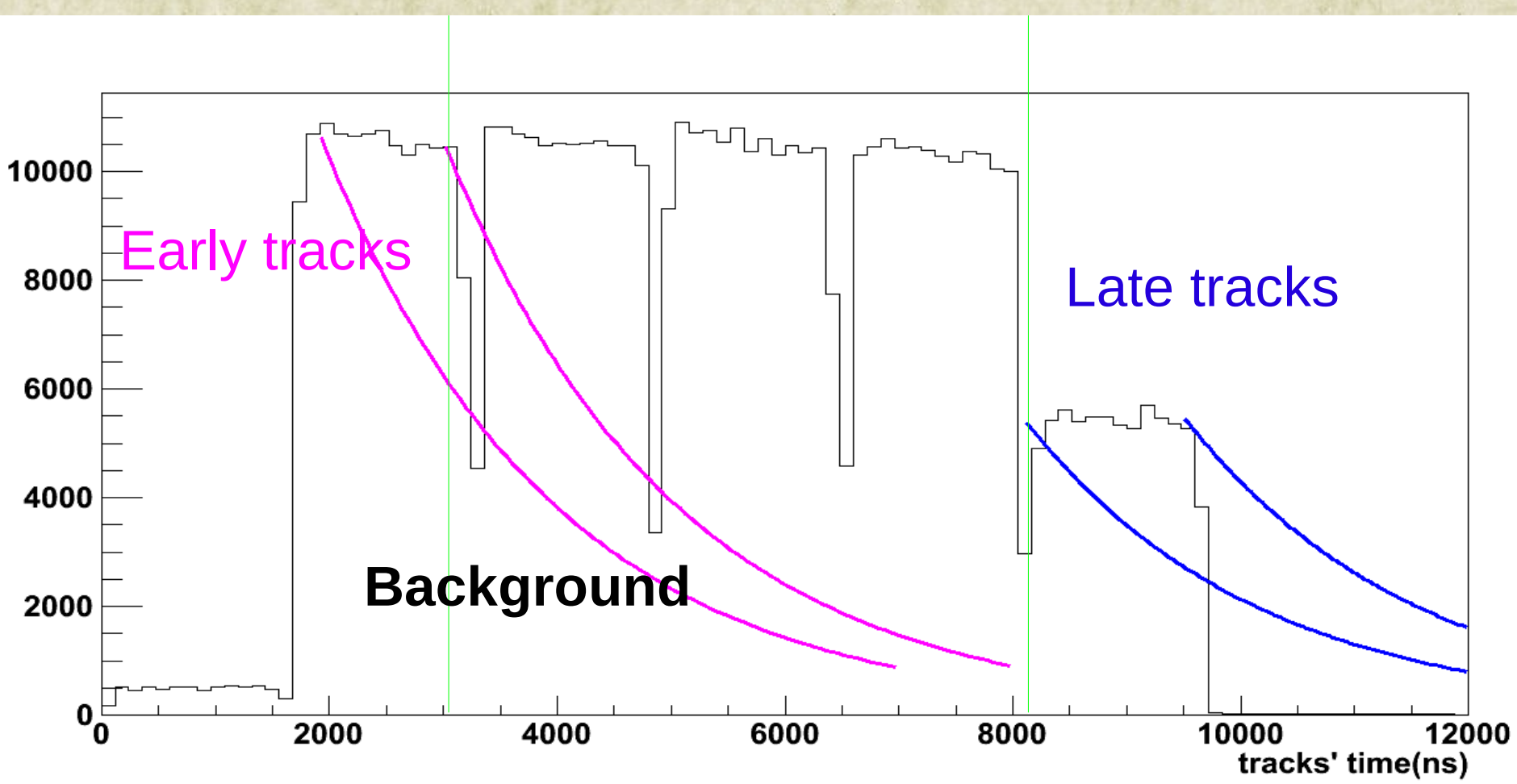




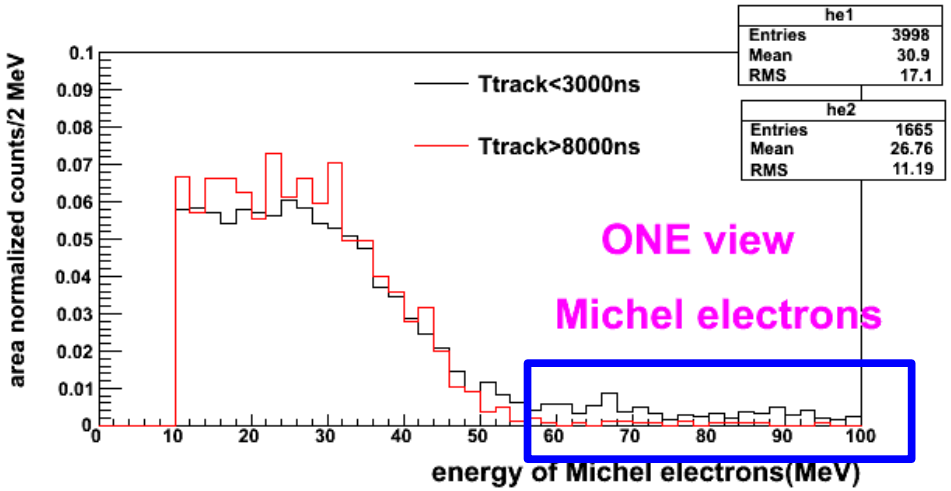


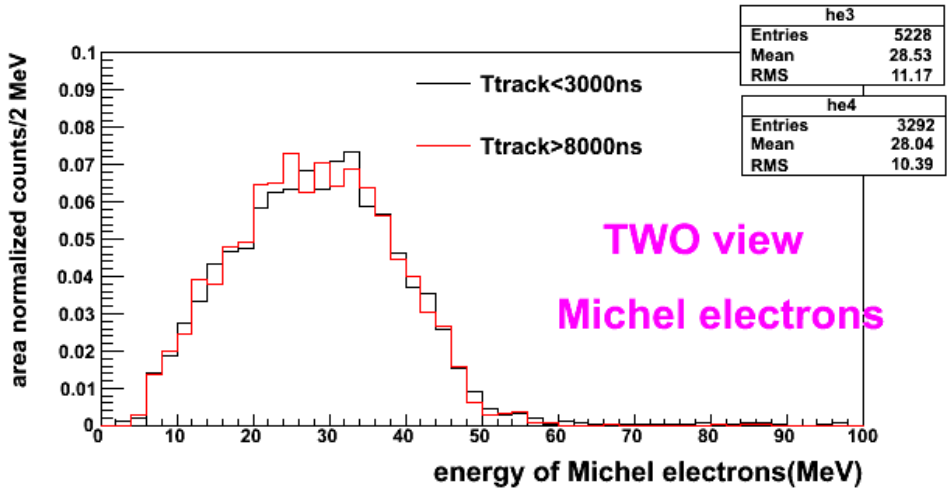
Background Study

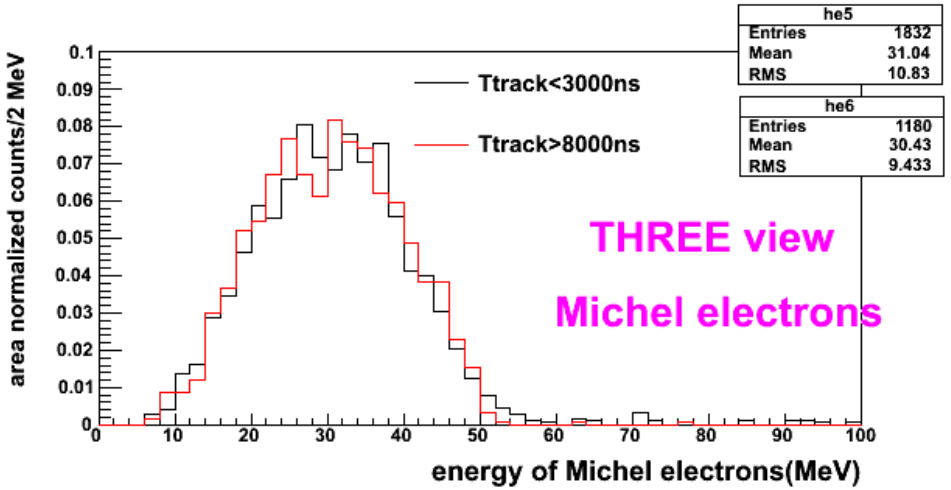
- We selected two subsets of our data sample, aiming to study the background
  - Early tracks < 3000ns and Late tracks > 8000ns

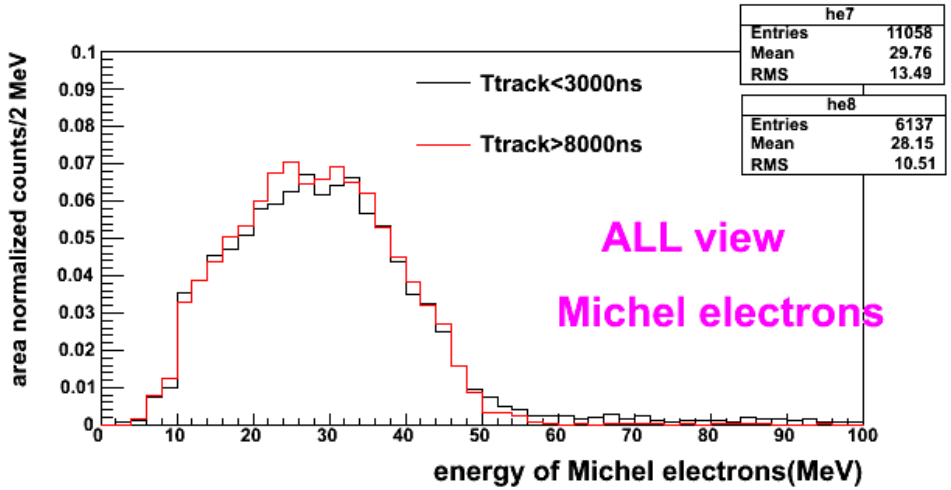


Energy distribution of Michel electrons from **early** and **late** tracks









Decay time distribution of Michel electrons from **early** and **late** tracks